Searching for Hotspots

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Isn't there an easy formula?

If we are estimating a mean:

$$n = \frac{(z_{1-\alpha/2})^2 s^2}{d^2} + \tfrac{1}{2} z_{1-\alpha/2}^2$$

If we are estimating a mean to make a decision:

$$n = \frac{(z_{1-\alpha} + z_{1-\beta})^2 s^2}{d^2} + \tfrac{1}{2} z_{1-\alpha}^2$$

and using either requires a random sample…

…but these are for means (averages)

- The formulae for estimating a mean will not work if the objective is the detection of the presence of a potential "hot-spot“.

- A different approach is needed, one that uses a grid to locate samples and a threshold value such that above this value implies a hotspot.

- The problem becomes:
  - How big is the potential hotspot
  - How large a mesh-spacing is needed
  - What is the chance of missing a hotspot

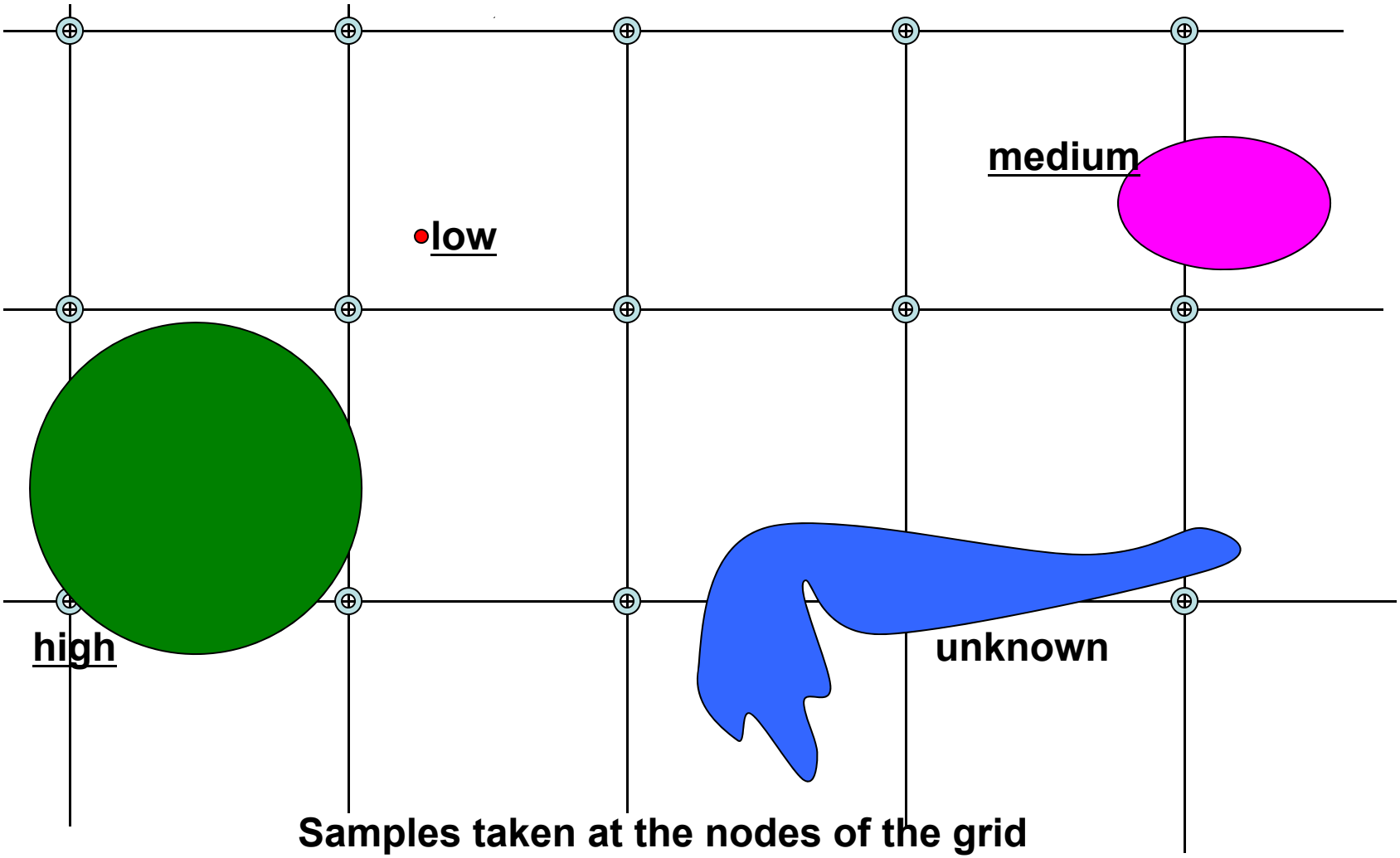
Specify one of the three

- How big is the potential hotspot?
- If hotspot is bigger than the mesh, then 100% chance!
- If very small then very low chance of catching it

- How large a mesh-spacing is needed?
- If large spacing used, then high risk of missing hotspot
- If small spacing, then will be collecting many samples

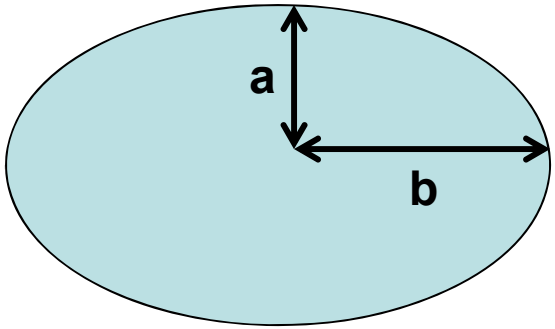
- What about the chance of missing a hotspot?
- Depends on how certain do you want to be
- If its important to find then will need many samples

Hot-Spot size, grid spacing, and probability of missing



How hot-spot sampling works

- You specify the size and decide if it is circular (radius "a") or elliptical (short arm "a", longer arm "b").

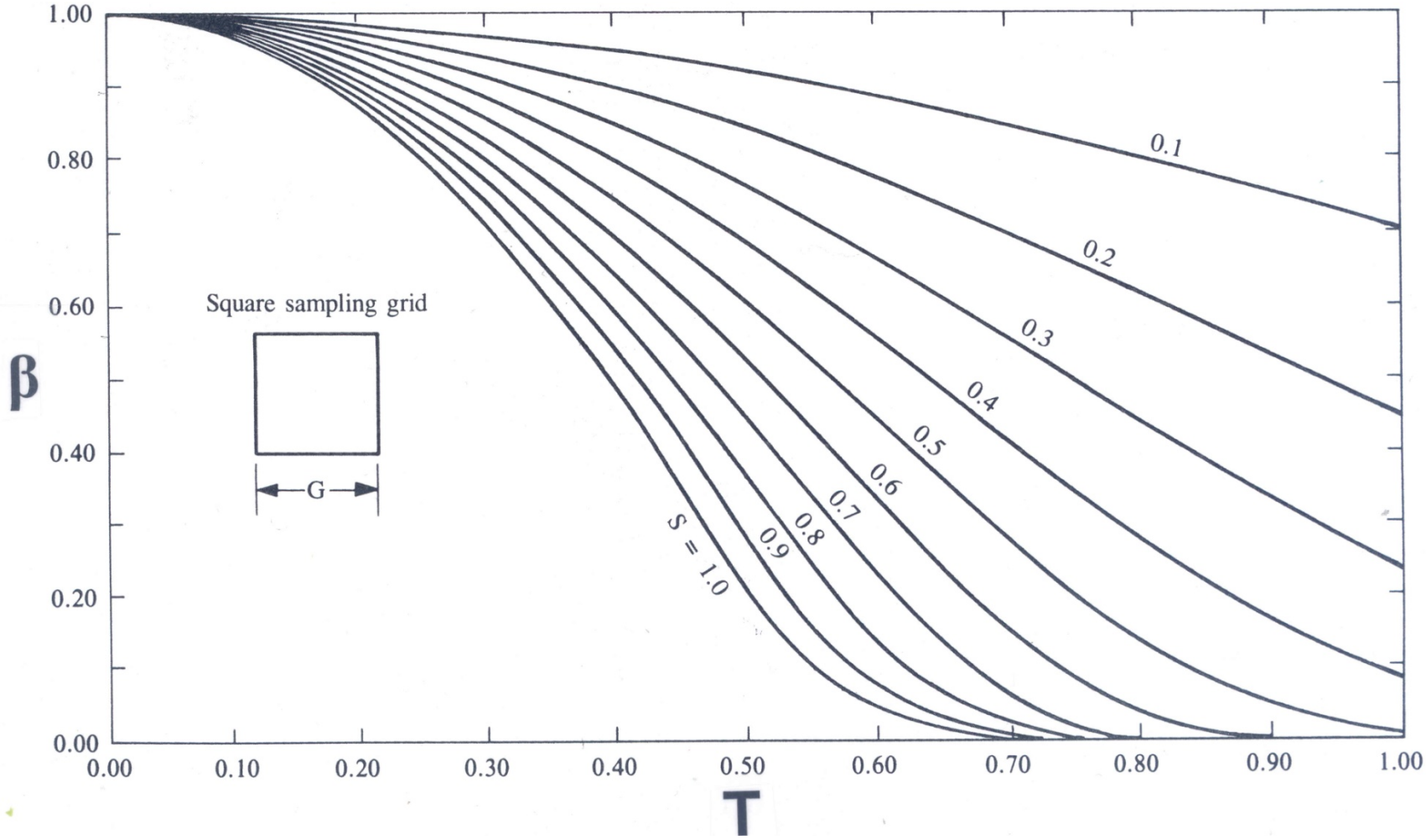


Calculate S = a/b

- You decide how much risk you are willing to take on missing hitting the hot-spot (the risk, probability "β").

- You use "β" and "S" with the following nomogram to find T, then the Grid mesh size, G = b/T.

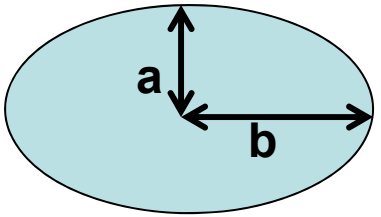
Hot-spot nomogram



Example: Hot-spot grid size calculation

4 acre abandoned property thought to have dispensed pesticides from a single location over 10 years ago. No information on probable location of filling area. 4 acres = roughly 4 football fields.

- **You specify the size and shape:**
  Elliptical, a=20ft, b=40ft



- **You decide risk of missing hitting hot-spot:**
  No more than a 10% chance (β = 0.10)

- **Calculate S = a/b: S = 20/40 = 0.50**

- **Use "β" and "S" with the nomogram to find T: T = 0.82**

- **Grid mesh size G = b/T: G = 40/0.82 = 48.8 ft**

Hot spot sampling (cont)

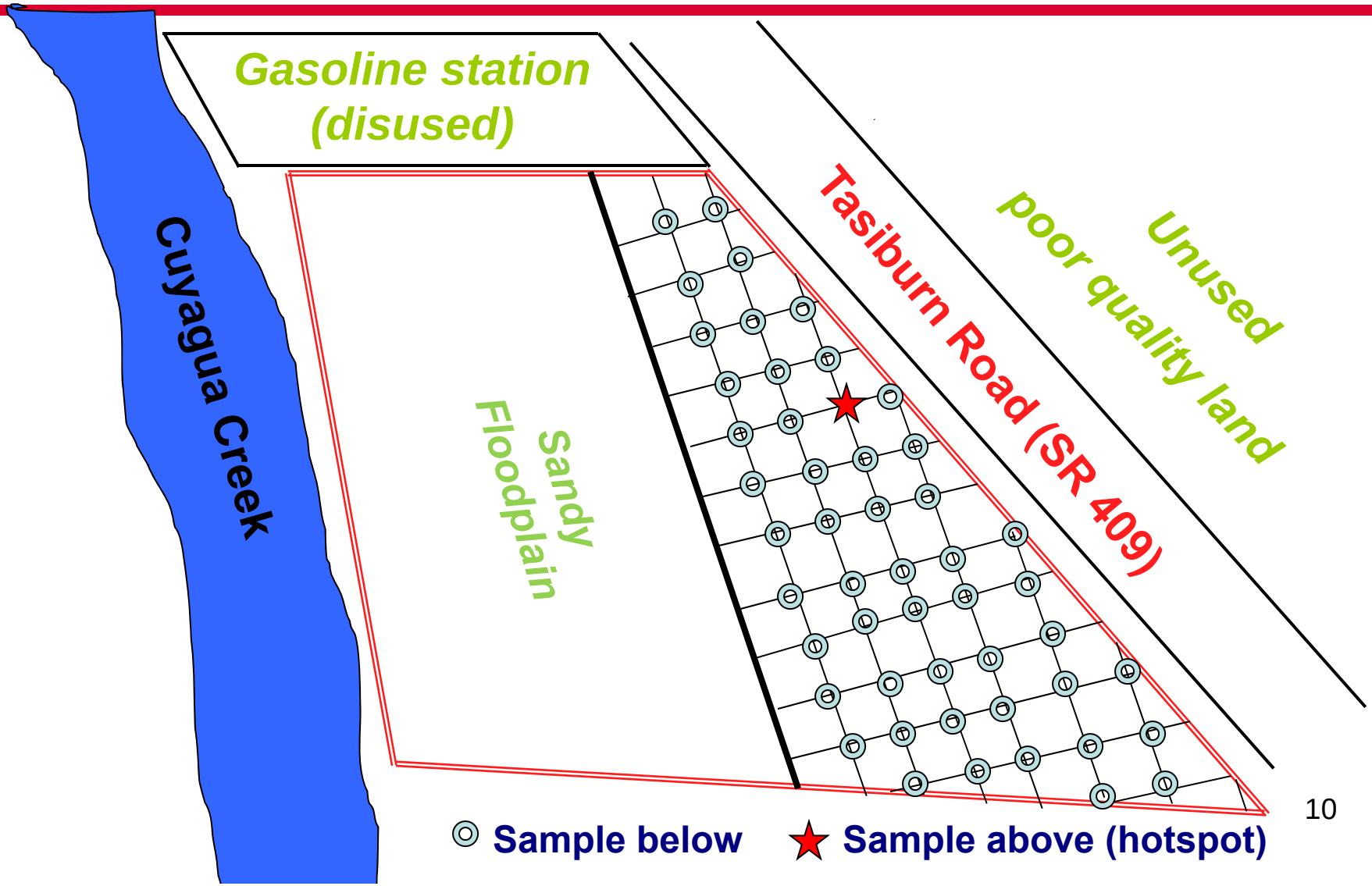
- Now asking a field crew to create a grid with a mesh size 48.8ft (48ft 9½in) is very difficult.

- Working backwards from the nomogram:
  - If 50ft mesh selected then $\beta = 0.17$ (17%)
  - If 45ft mesh selected then $\beta = 0.08$ (8%)

- Original requirement was β not to exceed 10% so a choice has to be made:

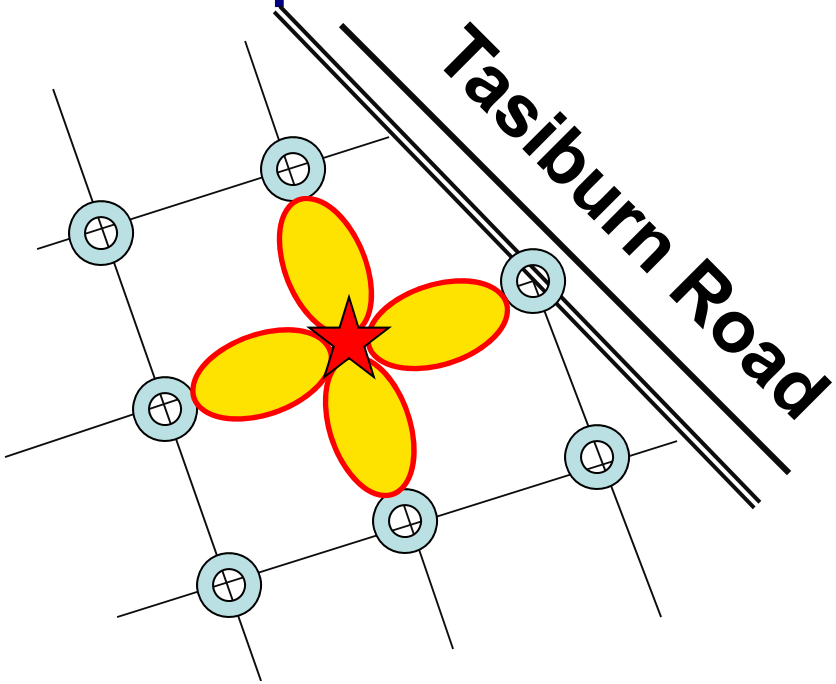
Select 50ft mesh with higher chance of missing hotspot or select 45ft mesh but take more samples?

Samples results compared to a threshold



Conclusions from the example

- Using a 50ft grid mesh we covered the site with 50 samples taken at the nodules of the grid
- 1 sample was above the threshold thus implying the potential existence of a hotspot

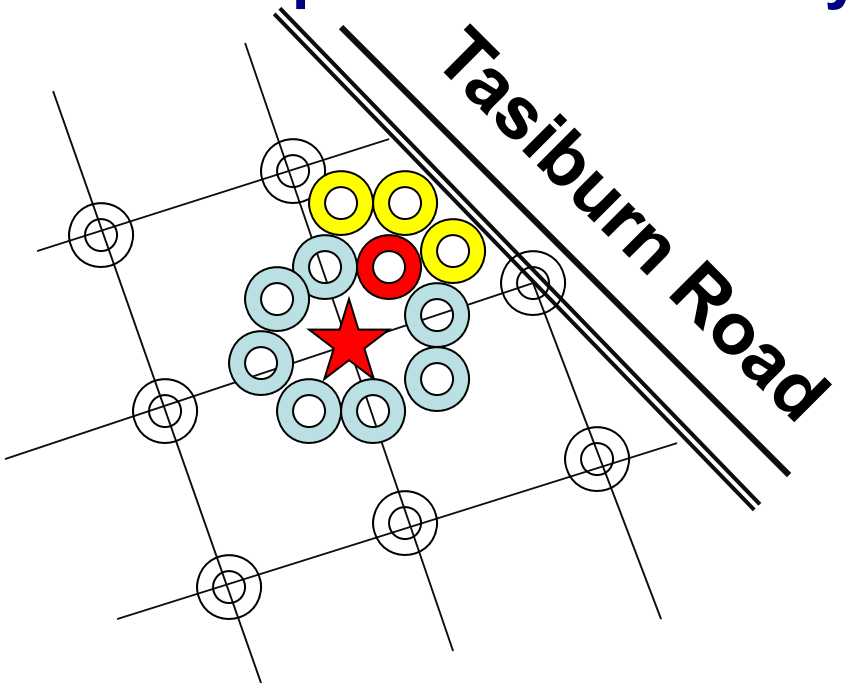


Hotspot

Potential extent of hotspot

Further sampling to determine the extent of the hotspot

- Using the position of the as the central location, further samples are taken around this position
- This is repeated until the boundaries of the hotspot are sufficiently delineated



Hotspot

Sample above threshold

Sample below threshold

Potential further samples

Hot Spot Sampling: Pro

- Very effective in finding hot spots of a specified size and shape
- Able to control the probability of missing a hot-spot of a given size
- Indirectly delineates the size and shape of the hot-spot
- Results can be used to guide further investigation

Hot Spot Sampling: Con

- Need to know what size and shape the potential hot-spot should be
- Need to decide the chance of missing a hot-spot of a certain size
- Could be expensive as you need to take samples from all over the grid

What can we infer (qualitatively)?

- Samples taken across the entire grid revealed a hot-spot, indicated by a red star 
- After identification of the hot spot, 8 extra samples were taken around the hot-spot but off the grid (recall initial samples were from the nodes of the grid mesh)
- 7 of the extra samples were considered "not hot"  , but 1 sample could be considered "hot"  , further samples could delineate the extent of the hotspot
- The hotspot is in the form of a plume stretching from Tasiburn Road roughly 60 ft into the field

Can we increase the quantitative information using extra samples?

- **No.** The new data is not random (like the original data) but deliberately selected as there was a hot-spot guiding them. You can't just add them together and expect the inferences (probabilities) to come out right.

- **Yes.** However, it is not straight-forward. This kind of sampling is known as Adaptive Cluster Sampling and you have to use special formulae to adjust for the fact you're using non-random samples.